III.A.3 Metal Interconnect for SOFC Power Systems

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Objectives

- Select a surface treatment process for commercial ferritic stainless steel to reduce oxide scale growth rate.
- Optimize treatment process conditions to provide a stable, conductive scale.
- Measure the scale properties in conditions relevant to solid oxide fuel cells (SOFCs).
- Evaluate treated metal interconnects under SOFC stack conditions.

Approach

- Select a heat treatment process to achieve a thin, dense scale of a conductive oxide composition.
- Measure scale conductivity in air at target operating temperature.
- Measure air-side scale conductivity when the opposite side is exposed to fuel conditions (dual atmosphere test condition).
- Evaluate scale morphology under fuel cell operating conditions.
- Evaluate the effect of surface treatment on chromium volatility.
- Measure interconnect repeat unit resistance under stack operating conditions.

Accomplishments

- The surface treatment was found to reduce the scale growth rate as determined by thermogravimetry at 750°C. The treated metal coupons showed a parabolic rate constant of 5×10^{-9} $gm^2/cm^4/hr$ compared to 7×10^{-8} $gm^2/cm^4/hr$ of uncoated coupons. The low oxidation rate of treated interconnects will enable achieving the target fuel cell operating life of 40,000 hours.
- Scale resistance was 10 $milliohm.cm^2$ in air at 750°C and less than one $milliohm.cm^2$ in humidified hydrogen.
- Scale morphology was characterized as a function of treatment process and test conditions relevant to fuel cell operation.
- Stable, low resistance was demonstrated under dual atmosphere test conditions.
- Significant reduction in chromium evaporation was observed with treated metal coupons.
- No detectable reactivity of treated metal and potential cell joining perovskite compositions was observed.

Future Directions

- Measurement of interconnect resistance in repeat unit test.
- Verification of performance improvement in fuel cell stack tests.

Introduction

Interconnects perform essential functions in a fuel cell stack, namely, electrical connection between adjacent cells and separation of air and fuel. In many cases, they also provide structural support for the stack. The use of a commercial alloy offers the potential for low-cost interconnect components that help to achieve the DOE target of low-cost, modular fuel cell stacks.

The SOFC interconnect must simultaneously satisfy several functional requirements. These functions require materials with high electronic conductivity for the series connection of individual single cells, gas impermeability to separate fuel and oxidant gases, chemical stability and conductivity over a large oxygen concentration range in order to maintain integrity in both the fuel and air atmospheres. Thermal expansion match with the rest of the cell elements is desired. Metal interconnects are very desirable from the viewpoint of manufacturing cost in addition to other functional requirements, provided that the high conductivity can be maintained at the operating conditions. Metal also lends itself to ease of fabrication of gas channels; greater control over dimensions to help improve the conformity; and uniform reactant distribution to ensure uniform current density, high fuel utilization and high fuel efficiency. The use of thin metallic sheets will reduce overall weight in the fuel cell system. High thermal conductivity of metal interconnects will help distribute the heat generated during the operation of the cell, thereby reducing the cooling air requirement as well as eliminating thermal stress failure of ceramic components caused by sharp thermal gradients.

The principal requirements of metal interconnects can be summarized as follows: 1) thermal expansion match with other cell components, 2) oxidation resistance in air and fuel at the operating temperature, 3) conductive interface (scale) in air and fuel atmospheres, 4) prevention of reactivity with electrode materials to form insulating compounds, 5) low volatility of major or minor constituents that poison electrode activity, 6) compatibility with anode and cathode environments, 7) uniformity in contact with the cells, 8) thermal cycle capability, and 9) cost. The present work focuses on the development and evaluation of conductive oxide scale on commercial ferritic stainless alloys.

Approach

A commercial stainless steel alloy was selected. The surface oxide scale was modified using an appropriate coating and heat treatment process to provide a dense conductive oxide scale. The growth rate, resistivity, and morphology of the scale were determined as a function of time for the various surface treatment conditions. The evaluations were made both in single atmosphere (air or fuel) and dual atmosphere (air and fuel on the opposite sides) conditions. Comparison of chromium evaporation characteristics of treated and untreated metal coupons was made using MgO powder as the chromium-getter.

Results

Thermogravimetry of a 400-series commercial stainless steel was performed. Both untreated and treated coupons were evaluated. Two types of treatments were done. The first one was to heat treat the coupon to grow a controlled, dense oxide scale layer (treatment 50C940). In a second variation, an additional treatment was performed to provide a stable chromium oxide composition as the outer layer (treatment MI2). The comparison of the oxide scale growth, via weight gain, is shown in Figure 1. The pre-grown oxide layer was found to reduce the scale growth significantly, while the second treatment provided an additional reduction in scale growth rate.

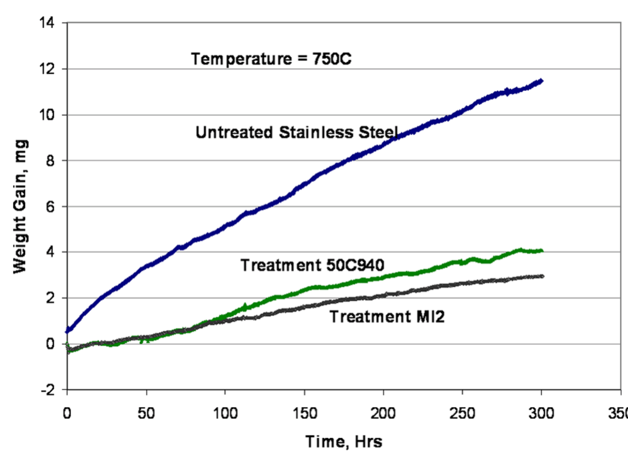

Figure 1. Thermogravimetry of Ferritic Stainless Steel Coupons

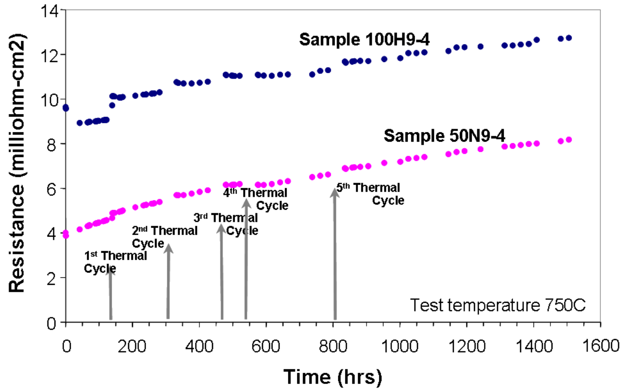

Figure 2. Resistance of Coupon Couples in Air at 750°C

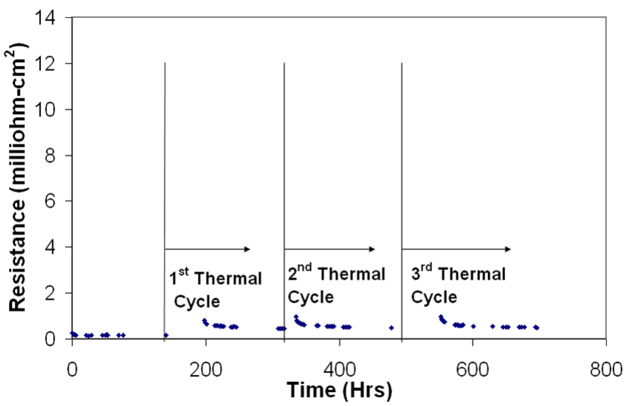

Figure 3. Resistance of Coupon Couples in Humidified Hydrogen at 750°C

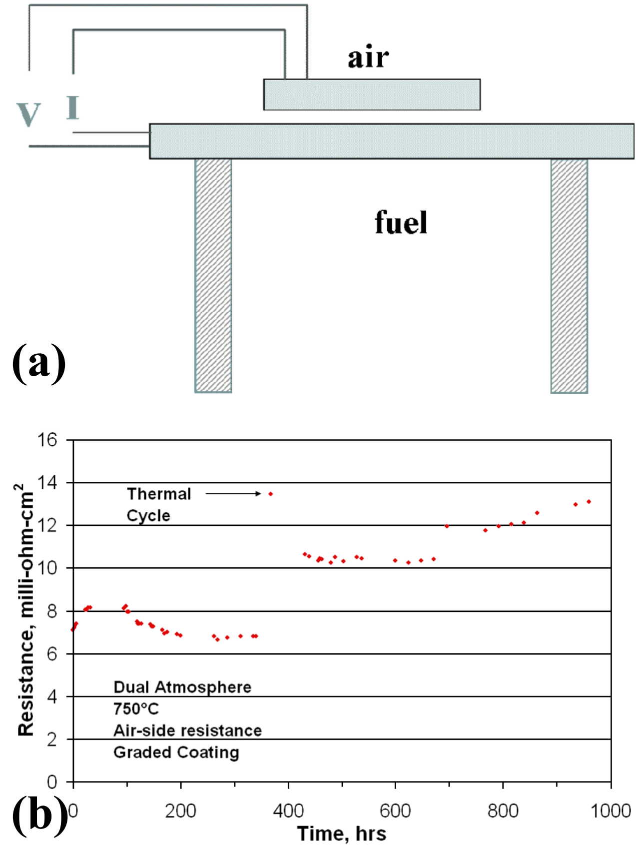

Figure 4. Test Configuration and Resistance of Coupon Couples in Dual Atmosphere

The resistances of the coupons were measured after they were surface treated. Two coupons were sandwiched using a conductive perovskite (e.g., cobaltite) as the contact paste. The change in measured resistance values of the coupon couples at 750°C in air is shown in Figure 2. The coupons were subjected to several thermal cycles. Similar measurements were also made in humidified hydrogen using nickel paste as the contact layer, shown in Figure 3. In both atmospheres, the resistance values were below 10 milliohm.cm^2, meeting the target interconnect resistance.

Earlier work showed that the oxide scale on the air side is disrupted when the opposite side is exposed to hydrogen at the target cell operating temperature. In order to evaluate the effect of dual atmosphere exposure, resistance of coupon couples was measured when one coupon was exposed to dual atmosphere. The test arrangement and the results of a test using the graded scale composition are shown in Figure 4. The low resistance measured under realistic exposure conditions is encouraging, although additional work is needed in characterizing possible changes in scale morphology under such conditions.

Chromium evaporation characteristics of the untreated and treated metal coupons were evaluated using an MgO-getter. A schematic of the test arrangement is shown in Figure 5. Various coupons were exposed to the getter material at 750°C for 300 hours. A significant reduction in chromium content was noted for the treated coupons, as shown in Table 1.

Table 1. ICP Analysis of Al_2O_3 Powder (ppm by weight)

	Baseline powder	Powder exposed to untreated coupon	Powder exposed to treated coupon	Powder exposed to treated and LSCo thermal sprayed coupon
Cr	< 0.5	250	140	4.1

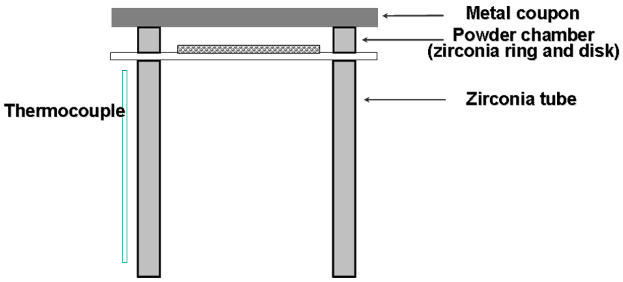

Figure 5. Test Configuration for Chromium Evaporation Assessment

Mixtures of treated and untreated stainless steel powder and perovkite powder were heat treated to evaluate the reactivity. The treated metal powder did not show any evidence of new phases based on X-ray diffraction analysis.

Conclusions

- Surface treatment to commercial ferritic stainless steel is shown to reduce the oxidation rate in air at SOFC operating temperature.
- The resistance values of the stainless interconnect meet the target.
- The surface treatment provides improved stability to the scale under dual atmosphere exposure conditions.
- A significant reduction in chromium evaporation rate was demonstrated.
- The treatment also suppresses reactivity of metal with cell joining perovskite materials.

FY 2005 Publications/Presentations

1. "Selection and Surface Treatment of Alloys in Solid Oxide Fuel Cell Systems," S. Elangovan, S. Balagopal, J. Hartvigsen, I. Bay, D. Larsen, M. Timper, and J. Pendleton, submitted to the Journal of Materials Engineering and Performance, 2005.
2. SECA Annual Workshop and Core Technology Program Peer Review Workshop, Pacific Grove, CA, April 2005.